And the tax winner is ... A note on endogenous timing in the commodity taxation race

Hubert Kempf, Grégoire Rota-Graziosi

Documents de Travail du
Centre d'Economie de la Sorbonne

CES Working Papers

And the tax winner is ...

A note on endogenous timing in the commodity taxation race

Hubert KEMPF, Grégoire ROTA-GRAZIOSI

2010.38

Maison des Sciences Économiques, 106-112 boulevard de L'Hôpital, 75647 Paris Cedex 13
http://ces.univ-paris1.fr/cesdp/CES-docs.htm
ISSN : 1955-611X

And the tax winner is ...

A note on endogenous timing in the commodity taxation race.

Hubert KEMPF[♯] and Grégoire ROTA-GRAZIOSI [‡]

♯: Paris School of Economics and Banque de France, Email: hubert.kempf@univ-paris1.fr

‡: CERDI-CNRS, Université d'Auvergne, Email: gregoire.rota_graziosi@u-clermont1.fr

May 24, 2010

Résumé

Cette note analyse le choix endogène de leadership entre deux pays se faisant concurrence sur la taxation des biens. Nous étudions un jeu d'échéancier, dans lequel les pays choisissent de faon crédible jouer comme meneur ou comme suiveur. Nous montrons que les équilibres parfaits en sous-jeux correspondent aux deux équilibres de Stackelberg, ce qui pose un problème de coordination. En sélectionnant un de ces équilibres par le biais du critère de risque-dominance, nous montrons que le petit pays doit mener. Si l'asymétrie entre les deux pays est suffisante, la Pareto-dominance renforce le critère de risque-dominance pour la sélection de cet équilibre. Nous en déduisons deux résultats importants pour la littérature sur la concurrence fiscale : quand les pays diffèrent suffisamment par leurs tailles, la règle selon laquelle le grand pays taxe plus ne tient pas; quand les pays sont similaires en taille, l'harmonisation fiscale par un taux d'imposition unique commun aux deux pays s'instaure spontanément.

JEL Codes: C72, H30, H87.

Key-words: Concurrence fiscale, complémentarité stratégigue, équilibre de Stackelberg, risque-dominance.

Abstract

This note investigates the endogenous choice of leadership in commodity tax competition. We apply an endogenous timing game, where jurisdictions commit themselves to lead or to follow, to the Kanbur and Keen (1993) model. We show that the Subgame Perfect Nash Equilibria (SPNE) correspond to the two Stackelberg situations, yielding to a coordination issue. Selecting an equilibrium by means of the risk-dominance criterion, we prove that the smaller country has to lead. If asymmetry among countries is sufficient, Pareto-dominance reinforces risk-dominance in selecting the same SPE. We deduce two important results for the literature of tax competition: when countries differ sufficiently by their size, the "big-country-higher-tax" rule does not hold anymore; when countries are close in size, tax harmonization through a unique tax rate among countries occurs without any international agreement.

JEL Codes: C72, H30, H87.

Key-words: Commitment; Commodity Tax Competition; Strategic Complements; Stackelberg Equilibrium; Pareto Dominance; Risk Dominance.

1 Introduction.

Taxes on consumption, such as excise taxes or Value Added Tax (VAT), are the most important sources of fiscal revenues in the European Union, accounting for more than 30% of overall taxation in OECD member countries. However, indirect tax differentials generate cross-border shopping, which constraints national governments in their tax policy and induces them to compete on tax rates.

Mintz and Tulkens (1986) provide the first formal analysis of commodity tax competition in a two-country model. They highlight the inefficiencies which arise from uncoordinated tax setting. Using a spatial representation of a two-country economy, Kanbur and Keen (1993) pursue the analysis and show that the smaller country sets the lower tax rate. This result, also called the "big-country-higher-tax-rate" rule, has been reinforced in the commodity tax competition context[1] by successive works such as Trandel (1994), Wang (1999) and Nielsen (2001).[2] However this rule is contradicted by several examples where smaller countries set higher tax rates: Canada vis-à-vis the US for income taxes, Denmark and Germany or Ireland and United Kingdom for VAT.[3] In order to contradict this rule, several solutions have been advanced in the literature. In a model where N countries are distributed along a representative segment, Ohsawa (1999) establishes a U-shape tax structure where the peripheral countries set higher tax rates. Nielsen (2002) assumes greater marginal costs of public funds in the smaller countries. Keen and Kotsogiannis (2002) consider the evasion on commodity taxation.

In general, these authors consider tax competition as a simultaneous (or static) game, where each country sets its tax policy, more specifically its tax rate, taking as given the tax rates of their neighbors. However the realism of simultaneous moves of countries when they decide their tax policy is questionnable. The sovereignty of countries gives them the opportunity to commit themselves to fiscal decisions. For Schelling (1960), the concept of

[1]It also holds in other contexts as capital tax competition.

[2]The former author distinguishes countries by their size rather than by their population density, while the latters assume that the large country decides on tax first.

[3]Remark that small countries like Denmark, Sweden and Finland set the highest VAT rates (25%, 25%, 22%, respectively) in the EU, while Germany or UK charge a relatively low VAT rate (19% and 15% respectively).

commitment turns upon the sequence of moves. He writes (page 124)

> "The commitment is a means of gaining *first move* in a game in which first move carries an advantage; the threat is a commitment to a strategy for *second move*."

Commitment may be achieved by moving earlier than the opponent. But in some environments acting after the other's decision may be more profitable. A dilemma then appears between committing to move early and forcing the others to best respond, and moving late so as to be able to play a best response against the opponent.

The aim of this note is to extend the model of Kanbur and Keen (1993) by taking into account the countries' capacity to commit to their tax policy move. We use the endogenous timing game, also named commitment game, proposed by Hamilton and Slutsky (1990).[4] We establish several results which are direct consequences of the strategic complementarity of national tax rates. Both countries have a second-mover advantage when they differ little in size; otherwise, the smaller country has a first-mover advantage, while the larger one prefers to follow. The Subgame Perfect Equilibria (SPNE) are the two Stackelberg situations where one of the two countries chooses first its tax rate, the other fixing its own policy after observing the behavior of the former. It appears unambiguously that moving sequentially is Pareto-improving compared to the standard simultaneous tax competition game.

Since we have multiple equilibria, we apply two equilibrium selection criteria: Pareto-dominance and Risk-dominance as defined by Harsanyi and Selten (1988). The SPNE where the smaller country leads risk-dominates the other SPNE. This result questions the relevance of the assumption advanced by Wang (1999) that the larger country leads. When asymmetry among countries is sufficient, Pareto-dominance reinforces risk-dominance by selecting the same SPNE. Two consequences follow which challenge existing results on commodity tax competition. First, when countries differ sufficiently in size, the smaller

[4]Kempf and Rota-Graziosi (2009) consider the capital taxation issue through a similar timing game. Kempf and Rota-Graziosi (2010) propose a taxonomy of international interactions depending on the sign of the spillovers and the nature of interactions (substitutes/complements).

country sets a higher tax rate than the larger one at the risk-dominant SPNE. In other terms, the “big-country-higher-tax-rate” rule does not hold anymore. Secondly, when countries are close in size, both countries choose the same tax rate at the risk-dominant SPNE. In this case, tax harmonization occurs whithout any international tax agreement.

The rest of the note is organized as follows. Section 2 presents the basic framework and the three simple games depending on the simultaneity or sequentiality of national tax-setting. In section 3, we address the endogenous timing game: we determine the SPNEs, highlighting a multiple equilibrium result; we then address the coordination issue by using the criteria of Risk-dominance and Pareto-dominance. Section 4 concludes.

2 A model of commodity taxation.

In this section, we strictly use the model developed by Kanbur and Keen (1993) and extended by Wang (1999).

2.1 The set-up.

We consider two countries, “home” and “foreign”, which might be represented by the interval $[-1, 1]$ with the border at the origin. The population is homogenous and uniformly distributed. The size of the home (respectively foreign) country is h (respectively H), with $h \leqslant H$. There is a single good consumed in both countries. Its pre-tax price is given and is the same in both countries. The price tag incorporates the commodity tax rate set by the country where the good is purchased. Each consumer buys one unit of the good. A home consumer pays the pre-tax price plus the home excise tax (t) if she buys in the home region; otherwise she pays the pre-tax price, the foreign excise tax (T), and the transportation cost ($\delta s > 0$) where s is the distance to the border and δ is the unit transportation cost. A consumer of the home country purchases the good in the foreign region if and only if

$$\frac{t-T}{\delta} > s \quad \text{and} \quad v - T - \delta s > 0,$$

where v is the consumer's reservation price. A similar setting applies to the foreign consumer. We assume that

$$(i)\ v \to \infty \quad \text{and} \quad (ii)\ \delta < 2. \tag{1}$$

The first condition insures that all agents will buy some goods and then pay the commodity tax. The second condition involves that the tax rate is less than unity for any degree of asymmetry, denoted by θ ($\theta = h/H \leq 1$).

The objective of each government is the maximization of its tax revenue. We then have:

$$\text{For } t \geqslant T, \qquad \begin{aligned} r(t,T) &= th\left(1 - \tfrac{t-T}{\delta}\right) \\ R(t,T) &= TH + Th\tfrac{t-T}{\delta} \end{aligned} \tag{2}$$

and

$$\text{For } t \leqslant T, \qquad \begin{aligned} r(t,T) &= th + tH\tfrac{T-t}{\delta} \\ R(t,T) &= TH\left(1 - \tfrac{T-t}{\delta}\right). \end{aligned} \tag{3}$$

We note that tax rates are *plain complements* in the terminology of Eaton (2004) as the payoff of a country increases in the tax rate of the other country: $\frac{\partial r(t,T)}{\partial T} \geqslant 0$ and $\frac{\partial R(t,T)}{\partial t} \geqslant 0$. [5]

The game proposed by Kanbur and Keen (1993) is supermodular.[6] This property insures the existence of a Nash equilibrium. It is also equivalent to the strategic complementarity of the tax rates: the marginal utility derived from an increase of the tax rate set by the home country is increasing in the tax rate of the foreign country.[7]

[5]This property always characterizes tax competition models, whatever the taxation basis (commodities, capital or labour).

[6]The supermodularity of the static game results from the supermodularity of the payoff functions. Whatever $t \geqslant T$ or $T \geqslant t$, we remark that the cross derivative of these functions is always positive: $\frac{\partial^2 r(t,T)}{\partial t \partial T} > 0$ and $\frac{\partial^2 R(t,T)}{\partial t \partial T} > 0$.

[7]Several recent works focusing on the estimation of the fiscal reaction functions in an international or federal context support the view that the slopes of reaction functions among countries are positive (see for instance Egger, Pfaffermayr, and Winner (2005) or Devereux, Lockwood, and Redoano (2007)). Lockwood and Migali (2009) show that the degree of fiscal interactions has increased among european countries since the the introduction of the Single Market in EU in 1993. They also observe that excise taxes are strategic complements.

2.2 Comparing non-cooperative games.

We consider three non-cooperative games: the simultaneous Nash equilibrium and the two Stackelberg ones, respectively denoted by Γ^N, Γ^h, and Γ^H. The first one has been studied by Kanbur and Keen (1993), the Stackelberg equilibrium where the larger country leads by Wang (1999), who also refers to the third one in a footnote.

The three basic games generate different tax rates. Drawing on these studies, we establish a ranking of the equilibrium tax rates in the following LEMMA:

Lemma 1 *Under condition (1), we have:*

$$For \quad \theta < \theta_1^c, \quad \begin{cases} t^N < t^F < t^L \\ T^N < T^L < T^F. \end{cases}$$

$$For \quad \theta \geqslant \theta_1^c, \quad \begin{cases} t^N < t^F < t^L \\ T^N < T^F < T^L, \end{cases}$$

where $\theta_1^c = \frac{\sqrt{7}-1}{2}$.

Proof. See APPENDIX B.3. ■

Consistent with the strategic complementarity property, tax rates in any Stackelberg equilibrium are higher than the rates obtained at the Nash equilibrium. When the leader, say the home country, increases its tax rate relative to the Nash equilibrium value, it induces the follower, the foreign country, to increase its own tax rate because of the strategic complementarity property. In turn, this increases the leader's payoff because of the plain complementarity of tax decisions. Hence we get $t^L > t^N$ and $T^F > T^N$. However it may happen that $T^F > T^L$. For a sufficient degree of asymmetry between country' sizes ($\theta < \theta_1^c$), the interaction effects are much stronger from the foreign country, which is also the larger one, to the home country, than from the home to to the foreign. Then t^L is very close to t^N and T^L is very far from T^N as well as t^F from t^N. This explains the obtained possible rankings. In brief, LEMMA (1) shows that the tax competition yields a lesser downward pressure in the sequential games than in the classic simultaneous one, or equivalently that the presence of a leader mitigates the "race-to-the-bottom" feature.

2.3 First-mover or second-mover advantages.

Given these rankings, we can now compare the payoffs in the three basic games (Γ^N, Γ^h and Γ^H), which will give us the opportunity of detecting potential first-mover or second-mover advantages. We define these concepts as follows: player i has a first-mover advantage (a second-mover advantage) if her equilibrium payoff in the Stackelberg game in which she leads, is higher (lower) than in the Stackelberg game in which she follows. Using these definitions, we establish the following PROPOSITION:

Proposition 1 *Under condition (1), we have:*
For $\theta < \theta_2^c$, the home (smaller) country has a first-mover advantage, while the foreign (larger) country has a second-mover advantage.
For $\theta \geqslant \theta_2^c$, both countries has a second-mover advantage.

Proof. See APPENDIX B.4. ■

The foreign country, the larger one, has always a second-mover advantage. If countries' sizes are close, both countries experiment a second-mover advantage. Being a follower allows a country both to benefit from higher tax rates compared to the Nash equilibrium and to have the lower tax rate, thus attracting cross-border shopping. In other terms, it free-rides the leader even though this free-riding is less important than in the simultaneous Nash game.

When asymmetry is sufficient ($\theta < \theta_2^c$), the smaller country has a first-mover advantage. By leading it expresses its relative weakness, which comes from its size relative to the foreign country. The home country increases its tax rate with respect to its Nash equilibrium level and then incites the foreign country to increase its tax rate too, by so doing reducing the free-riding mechanism due to tax competition.

3 The endogenous timing game.

These results imply that the existence and identity of a leader matter a lot in the tax competition race. Hence we would like to know the identity of the leader if it exists: is it the home or foreign country? To answer this question, we turn to the endogenization of moves, using a timing game.

3.1 The Subgame Perfect Nash Equilibria (SPNE).

Following Hamilton and Slutsky (1990), we consider an extended game, denoted by $\widetilde{\Gamma}$ **and defined as follows.** At the first or "preplay" stage, players simultaneously and non-cooperatively decide whether to move "early" or "late". The players' commitment to this choice is perfect. The timing choice of each player is announced at the end of the first stage. The second stage corresponds to the relevant tax competition game studied in the previous section, which is deduced from the timing decision at the first stage: the game (Γ^N) if both players choose to move early or late; the Stackelberg game (Γ^h) if the home country chooses to move early (strategy *Early*) while the foreign country chooses to move late (strategy *Late*); the Stackelberg game (Γ^H) if the timing of decisions is reversed. This game can be expressed by the following 2×2 normal form:[8]

Table 1: Normal form of the game $\widetilde{\Gamma}$

		Foreign country	
		Early	*Late*
Home	*Early*	r^N, R^N	r^L, R^F
country	*Late*	r^F, R^L	r^N, R^N

From the preceding normal form of the game $\widetilde{\Gamma}$, we obtain the following Proposition:

Proposition 2 *The Subgame Perfect Nash equilibria (SPNEs) correspond to the Stackelberg outcomes.*

Proof. See Appendix B.5. ■

The two possible Stackelberg equilibria are solutions to the timing game $\widetilde{\Gamma}$. This comes from the fact that in any case, both the first- and second-movers are better off than under a Nash equilibrium. At the SPNEs, since tax rates are strategic complements, the tax rates

[8] We define: $r^N = r\left(t^N, T^N\right)$, $R^N = R\left(t^N, T^N\right)$, $r^F = r\left(t^F\left(T^L\right), T^L\right)$, $r^L = r\left(t^L, T^F\left(t^L\right)\right)$, $R^L = R\left(t^F\left(T^L\right), T^L\right)$, and $R^F = R\left(t^L, T^F\left(t^L\right)\right)$.

are in both countries superior to those established at the simultaneous Nash equilibrium. The "race-to-bottom" is weaker as it is predicted in the standard tax competition model. The SPNEs are Pareto-superior to the simultaneous Nash Equilibrium ($W_i^{F,L} > W_i^N$). Both countries have a common interest in avoiding the Nash tax rates, and they can do so by resorting to non-synchronous moves, that is by accepting that one of them leads the tax competition race.[9]

3.2 Risk-dominance.

Given the multiplicity of SPNEs of $\widetilde{\Gamma}$, a coordination issue arises: how to select one of the two possible solutions? To solve this issue, we can resort to two criteria in order to rank the SPNEs: the Pareto-dominance and the risk-dominance criteria. Harsanyi and Selten (1988) define the latter criterion as follows:

Definition 1 *An equilibrium risk-dominates another equilibrium when the former is less risky than the latter, that is the risk-dominant equilibrium is the one for which the product of the deviation losses is the largest.*

The equilibrium where the home country leads and the foreign one follows, denoted by $(Early, Late)$, risk-dominates the equilibrium where the foreign country leads and the home one follows, denoted by $(Late, Early)$, if the former is associated with the larger product of deviation losses, or more formally, if and only if

$$\Pi = \left(r^L - r^N\right)\left(R^F - R^N\right) - \left(r^F - r^N\right)\left(R^L - R^N\right) > 0. \tag{4}$$

Applying this definition we obtain the following Proposition

Proposition 3 *Under condition (1),*

1. *The SPNE where the smaller country leads risk-dominates the other SPNE for every value of θ.*
2. *For $\theta < \theta_2^c$, the SPNE where the smaller country leads Pareto-dominates the other SPNE.*

[9] We remark that the equilibrium studied by Kanbur and Keen (1993) is not a *Commitment Robust Nash Equilibrium*, as defined by van Damme and Hurkens (1996). For these authors, a Nash Equilibrium is a *Commitment Robust Nash Equilibrium*, if and only if no country has a first-mover incentive.

Proof. See Appendix B.6. ■

At the risk-dominant SPNE, the home country has to move early since it has more to lose in the simultaneous game than the other country. The home country increases its own tax rate compared to the Nash level, which will trigger a larger increase in the tax rate of the foreign country because of the complementarity effect; on the other hand, if the foreign country is a leader (*Early*), given that the home country as a follower (*Late*) will not tend to act much, the gain of the foreign country as a leader with respect to the Nash solution, is **smaller**. When the asymmetry is sufficient, the SPNE where the smaller country leads is Pareto-superior to the other SPE. Indeed, the home country experiments a first-mover advantage, while the other has a second-mover advantage. By leading and fixing a higher tax rate, the home country encourages the foreign country to increase its tax rate. Thus, Pareto-dominance reinforces risk-dominance when asymmetry between countries is sufficient.

An imediate Corolloray of our results is the following:

Corollary 1 *At the risk-dominant SPNE (Early, Late), we have*

$$t^L = T^F \quad for \quad \theta \leqslant \frac{1}{2},$$

and

$$t^L > T^F \quad for \quad \theta > \frac{1}{2}.$$

Proof. See Appendix B.7. ■

While at the simultaneous Nash equilibrium, the larger country always sets the highest tax rate due to its relatively low elasticity of tax base to the tax rate, it sets the lowest tax rate at the risk-dominant SPNE when θ is bigger than 1/2. When countries differ sufficiently in size like Denmark and Germany for instance, the following larger country extracts more revenues by undercutting the tax rate of the leading smaller country and attracting more consumers. Thus, the “big-country-higher-tax-rate” rule, which was first emphasized by Bucovetsky (1991) in the context of capital taxation, does not hold anymore. A final comment for this case is to highlight that the ex ante advantage in size of the larger country is reinforced through the second-mover advantage.

When the countries' sizes are close, like France and Germany for instance, the larger country is able to stem off the crowding out of consumers by setting the same rate as the leading country.[10] Tax harmonization, defined as a unique tax rate among countries, then occurs without any international tax agreement and cross-border shopping obviously disappears.

4 Conclusion.

This paper adopts the approach of Kanbur and Keen (1993) to apprehend commodity tax competition. Applying the endogenous timing game developed by Hamilton and Slutsky (1990), we endogeneize the sequence of players' moves. We establish that the smaller country sets first its tax rate at the risk-dominant Subgame Perfect Nash Equilibrium. This impacts on the outcome of the tax competition race. The "big-country-higher-tax" rule does not hold anymore: when countries' sizes are sufficiently different, the smaller country sets higher tax rate than the larger country. When sizes are sufficiently close, then the two countries set an identical tax rate and tax harmonization occurs.

We have highlighted the importance of the second-mover advantage in tax competition. An extension of our analysis would be to determine how a country can commit to a second move as far as its tax policy is concerned. For instance, a ratification requirement has been seen as a commitment's device to a second move in international negotiations. We can note that the political process of tax policy markedly differs across countries and gives governments more or less commitment capacity in their decisions on tax rates.

[10]The VAT rates which were respectively 20% for France and 11% for Germany in 1973, converge to $19,6\%$ for France and 19% for Germany in 2009.

References

Baldwin, R. E., and P. Krugman (2004): "Agglomeration, integration and tax harmonisation," *European Economic Review*, 48(1), 1–23.

Bucovetsky, S. (1991): "Asymmetric tax competition," *Journal of Urban Economics*, 30(2), 167–181.

Devereux, M., B. Lockwood, and M. Redoano (2007): "Horizontal and vertical indirect tax competition: Theory and some evidence from the USA," *Journal of Public Economics*, 91(3-4), 451–479.

Eaton, B. C. (2004): "The elementary economics of social dilemmas," *Canadian Journal of Economics*, 37(4), 805–829.

Egger, P., M. Pfaffermayr, and H. Winner (2005): "Commodity taxation in a 'linear' world: a spatial panel data approach," *Regional Science and Urban Economics*, 35(5), 527–541.

Hamilton, J. H., and S. M. Slutsky (1990): "Endogenous timing in duopoly games: Stackelberg or Cournot equilibria," *Games and Economic Behavior*, 2(1), 29–46.

Harsanyi, J. C., and R. Selten (1988): *A general theory of equilibrium selection in games*. MIT Press, Cambridge, MA.

Kanbur, R., and M. Keen (1993): "Jeux sans frontieres: tax competition and tax coordination when countries differ in size," *American Economic Review*, 83(4), 877–92.

Keen, M., and C. Kotsogiannis (2002): "Leviathan and capital tax competition in federations," *American Economic Review*, 92(1), 363–370.

Kempf, H., and G. Rota-Graziosi (2010): "Endogenizing leadership in tax competition," *Journal of Public Economics*, forthcoming.

——— (2010): "Leadership in public good provision: a timing game perspective," *Journal of Public Economic Theory*, forthcoming.

LOCKWOOD, B., AND G. MIGALI (2009): "Did the single market cause competition in excise taxes? Evidence from EU countries," *Economic Journal*, 119(536), 406–429.

MINTZ, J., AND H. TULKENS (1986): "Commodity tax competition between member states of a federation: equilibrium and efficiency," *Journal of Public Economics*, 29(2), 133–172.

NIELSEN, S. B. (2001): "A simple model of commodity taxation and cross-border shopping," *Scandinavian Journal of Economics*, 103(4), 599–623.

——— (2002): "Cross-border shopping from small to large countries," *Economics Letters*, 77(3), 309–313.

OHSAWA, Y. (1999): "Cross-border shopping and commodity tax competition among governments," *Regional Science and Urban Economics*, 29(1), 33–51.

RAIMONDOS-MØLLER, P., AND A. D. WOODLAND (2000): "Tariff strategies and small open economies," *Canadian Journal of Economics*, 33(1), 25–40.

SCHELLING, T. (1960): *The strategy of conflict*. Harvard University Press, Cambridge, MA.

TRANDEL, G. A. (1994): "Interstate commodity tax differentials and the distribution of residents," *Journal of Public Economics*, 53(3), 435–457.

VAN DAMME, E., AND S. HURKENS (1996): "Commitment robust equilibria and endogenous timing," *Games and Economic Behavior*, 15(2), 290–311.

WANG, Y.-Q. (1999): "Commodity taxes under fiscal competition: Stackelberg equilibrium and optimality," *American Economic Review*, 89(4), 974–981.

A Appendix.

Borrowing from Kanbur and Keen (1993) and Wang (1999), the following results obtain.

The best-reply correspondances obtain:

$$t(T) = \begin{cases} \frac{1}{2}(\delta + T) & if \quad T \geqslant \delta\sqrt{\theta} \\ \frac{1}{2}(\delta\theta + T) & if \quad T \leqslant \delta\sqrt{\theta} \end{cases}$$

and

$$T(t) = \begin{cases} \frac{1}{2}(\delta + t) & if \quad t \leqslant \delta \\ t \quad if & \delta \leqslant t \leqslant \frac{\delta}{\theta} \\ \frac{1}{2}\left(\frac{\delta}{\theta} + t\right) & if \quad t \geqslant \frac{\delta}{\theta}. \end{cases}$$

Hence the solution of the Nash non-cooperative equilibrium is:

$$\begin{cases} t^N = \frac{\delta}{3}(1 + 2\theta) \\ T^N = \frac{\delta}{3}(2 + \theta) \end{cases} \tag{5}$$

and

$$\begin{cases} r\left(t^N, T^N\right) = \frac{\delta}{9}H(1 + 2\theta)^2 \\ R\left(T^N, t^N\right) = \frac{\delta}{9}H(2 + \theta)^2. \end{cases} \tag{6}$$

The solution to the Stackelberg game where the home country leads, is:

$$\begin{array}{l} t^L = T^F = \frac{\delta}{\theta} \quad for \quad \theta \leqslant \frac{1}{2}, \\ \begin{cases} t^L = \delta\left(1 + \frac{1}{2\theta}\right) \\ T^F = \frac{1}{2}\delta\left(1 + \frac{3}{2\theta}\right) \end{cases} \quad for \quad \theta \geqslant \frac{1}{2}, \end{array} \tag{7}$$

and

$$\begin{array}{l} r\left(t^L, T^F\right) = \begin{cases} H\delta & \text{if} \quad \theta \leqslant \frac{1}{2} \\ \frac{\delta h}{8}\left(2 + \frac{1}{\theta}\right)^2 & \text{if} \quad \theta \geqslant \frac{1}{2} \end{cases}. \\ R\left(t^L, T^F\right) = \begin{cases} H\frac{\delta}{\theta} & \text{if} \quad \theta \leqslant \frac{1}{2} \\ \frac{\delta h}{16}\left(2 + \frac{3}{\theta}\right)^2 & \text{if} \quad \theta \geqslant \frac{1}{2} \end{cases} \end{array} \tag{8}$$

The solution to the Stackelberg game where the foreign country leads, is:

$$\begin{cases} t^F = \frac{\delta}{2}\left(1 + \frac{3}{2}\theta\right) \\ T^L = \frac{\delta}{2}(2 + \theta) \end{cases} \tag{9}$$

and

$$\begin{cases} r\left(t^F, T^L\right) = \frac{\delta}{16}H(2 + 3\theta)^2 \\ R\left(t^F, T^L\right) = \frac{\delta}{8}H(2 + \theta)^2. \end{cases} \tag{10}$$

Comparing the tax rates, From (12), (14) and (16), we get:

$$t^N < t^F < t^L$$

and

$$\begin{aligned} T^N &< T^L < T^F \quad for \quad \theta < \theta_1^c = \frac{\sqrt{7} - 1}{2} \approx 0.822876, \\ T^N &< T^F < T^L \quad for \quad \theta \geq \theta_1^c. \end{aligned}$$

From (13), (15) and (17), we can derive the first-mover or second-mover advantages:
For $\theta \in [0,1]$,

$$R\left(t^L, T^F\right) > R\left(t^F, T^L\right).$$

If $\theta < \theta_2^c \approx 0.68896$,

$$r\left(t^L, T^F\right) > r\left(t^F, T^L\right).$$

If $\theta \geqslant \theta_2^c$,

$$r\left(t^L, T^F\right) \leqslant r\left(t^F, T^L\right).$$

From Proposition 1, (13), (15) and (17), we get:

$$\begin{array}{rcl} R\left(t^F, T^L\right) & > & R\left(t^N, T^N\right) \quad and \quad R\left(t^L, T^F\right) > R\left(t^N, T^N\right), \\ r\left(t^F, T^L\right) & > & r\left(t^N, T^N\right) \quad and \quad r\left(t^L, T^F\right) > r\left(t^N, T^N\right). \end{array}$$

When the home country plays *Early*, the foreign always prefers to follows; if the foreign plays *Late*, the home country prefers to lead. Thus the Stackelberg situation where the home country leads is a SPNE. In a similar way, we establish that the other Stackelberg outcome is a SPNE too.

We are now able to apply the risk-dominance criterion and prove (1) :
If $\theta < \frac{1}{2}$,

$$\Pi = \frac{(2+\theta)\left(512 - 744\theta - 12\theta^2 + 162\theta^3 + 55\theta^4\right)}{1152\theta}\delta^2 H^2 > 0.$$

If $\theta \geqslant \frac{1}{2}$,

$$\Pi = \frac{81 + 296\theta + 136\theta^2 - 400\theta^3 - 248\theta^4 + 80\theta^5 + 55\theta^6}{1152\theta^2}\delta^2 H^2 > 0.$$

The proof of (2) is immediate from Proposition 1.

Finally, the Stackelberg equilibrium when the home country leads $\left(t^L, T^F\right)$ is characterized by:[11]

$$t^L = t^F = \frac{\delta}{\theta} \quad for \quad \theta \leqslant \frac{1}{2},$$

and

$$\left\{ \begin{array}{l} t^L = \delta\left(1 + \frac{1}{2\theta}\right) \\ T^F = \frac{\delta}{2}\left(1 + \frac{3}{2\theta}\right) \end{array} \right. \quad for \quad \theta \geqslant \frac{1}{2}.$$

□

B Detailed Appendix.

This appendix develops the previous one and is not for publication.

B.1 The best-reply correspondances.

All proofs presented in this appendix summmarize or elaborate on results obtained in Kanbur and Keen (1993) and Wang (1999).

- Assuming $t \geqslant T$, the objective functions are given by expressions (2). We obtain the following

[11] This result is already presented in footnote 5, p.976, in Wang (1999) paper.

best-reply correspondences which correspond to interior solutions:

$$\begin{aligned}\frac{\partial r(t,T)}{\partial t} &= 0 \Leftrightarrow t(T) = \frac{1}{2}(\delta + T).\\ \frac{\partial R(t,T)}{\partial T} &= 0 \Leftrightarrow T(t) = \frac{1}{2}\left(\frac{\delta}{\theta} + t\right).\end{aligned}$$

These results hold if:

$$t \geqslant T \Leftrightarrow \begin{cases} T \leqslant \delta \\ t \geqslant \frac{\delta}{\theta}. \end{cases}$$

- Assuming $t \leqslant T$, the objective functions are given by expressions (3). We have:

$$\begin{aligned}\frac{\partial r(t,T)}{\partial t} &= 0 \Leftrightarrow t(T) = \frac{1}{2}(\delta\theta + T)\\ \frac{\partial R(t,T)}{\partial T} &= 0 \Leftrightarrow T(t) = \frac{1}{2}(\delta + t).\end{aligned}$$

These results hold if:

$$t \leqslant T \Leftrightarrow \begin{cases} T \geqslant \delta\theta \\ t \leqslant \delta. \end{cases}$$

- Assuming $t = T$, the objective functions may be given by expressions (2) or (3). However the best-reply functions correspond to corner solutions. For instance, we consider the case where $t \geqslant T$ and then expressions (2). We get:

$$\begin{aligned}\frac{\partial r(t,T)}{\partial t} &\leqslant 0 \Leftrightarrow t \geqslant \delta\\ \frac{\partial R(t,T)}{\partial T} &\geqslant 0 \Leftrightarrow t \leqslant \frac{\delta}{\theta}.\end{aligned}$$

Thus we get:

$$T = t \quad for \quad \delta \leqslant t \leqslant \frac{\delta}{\theta}.$$

- For $\delta\theta \leqslant T \leqslant \delta$, comparing the objective function levels of the home country, we conclude:

$$\begin{aligned}\text{For } t &\geqslant T, \quad r\left(\frac{1}{2}(\delta + T), T\right) = \frac{H}{4\delta}(T + \delta\theta)^2.\\ \text{For } t &\leqslant T, \quad r\left(\frac{1}{2}(\delta\theta + T), T\right) = \frac{h}{4\delta}(T + \delta)^2.\end{aligned}$$

Thus:

$$r\left(\frac{1}{2}(\delta + T), T\right) > r\left(\frac{1}{2}(\delta\theta + T), T\right) \Leftrightarrow T > \delta\sqrt{\theta}.$$

In brief, we obtain:

$$t(T) = \begin{cases} \frac{1}{2}(\delta + T) \quad if \quad T \geqslant \delta\sqrt{\theta} \\ \frac{1}{2}(\delta\theta + T) \quad if \quad T \leqslant \delta\sqrt{\theta} \end{cases}$$

and

$$T(t) = \begin{cases} \frac{1}{2}(\delta + t) \quad if \quad t \leqslant \delta \\ t \quad if \quad \delta \leqslant t \leqslant \frac{\delta}{\theta} \\ \frac{1}{2}\left(\frac{\delta}{\theta} + t\right) \quad if \quad t \geqslant \frac{\delta}{\theta}. \end{cases}$$

□

B.2 The resolution of the three basic games.

B.2.1 Nash non-cooperative Equilibrium.

1. Assuming $T \leqslant \delta\sqrt{\theta}$, we get: $t(T) = \frac{1}{2}(\delta + T)$.

   - For $t \leqslant \delta$, $T(t) = \frac{1}{2}(\delta + t)$ and $T < t$, we obtain by substitution:
   $$T = \delta = t,$$
   which is valid only if $\theta = 1$.
   - For $\delta < t < \frac{\delta}{\theta}$, $T(t) = t$, we obtain by substitution:
   $$T = \delta = t,$$
   which contradicts $\delta < t < \frac{\delta}{\theta}$.
   - For $t \geqslant \frac{\delta}{\theta}$, $T(t) = \frac{1}{2}\left(\frac{\delta}{\theta} + T\right)$ and $t < T$, we obtain by substitution:
   $$\begin{cases} T = \frac{\delta}{3}\left(1 + \frac{2}{\theta}\right) \\ t = \frac{\delta}{3}\left(2 + \frac{1}{\theta}\right) \end{cases}$$
   which is impossible since $\frac{\delta}{3}\left(2 + \frac{1}{\theta}\right) \leqslant \frac{\delta}{\theta}$ contradicts the assumption $t \geqslant \frac{\delta}{\theta}$.

2. Assuming $T \geqslant \delta\sqrt{\theta}$, we get: $t(T) = \frac{1}{2}(\delta\theta + T)$.

   - For $t \leqslant \delta$, $T(t) = \frac{1}{2}(\delta + t)$ and $T < t$, we obtain by substitution:
   $$\begin{cases} T^N = \frac{\delta}{3}(2 + \theta) \\ t^N = \frac{\delta}{3}(1 + 2\theta) \end{cases} \tag{11}$$
   which is valid, since the conditions $T \geqslant \delta\sqrt{\theta}$ and $t \leqslant \delta$ hold.
   - For $\delta < t < \frac{\delta}{\theta}$, $T(t) = t$, we obtain by substitution:
   $$T = t = \delta\theta,$$
   which contradicts $\delta \leqslant t$ if $\theta < 1$.
   - For $t \geqslant \frac{\delta}{\theta}$, $T(t) = \frac{1}{2}\left(\frac{\delta}{\theta} + t\right)$ and $t < T$, we obtain by substitution:
   $$\begin{cases} T^N = \frac{\delta}{3\theta}\left(\theta^2 + 2\right) \\ t^N = \frac{\delta}{3\theta}\left(2\theta^2 + 1\right) \end{cases}$$
   which contradicts $t \geqslant \frac{\delta}{\theta}$ for $\theta < 1$.

To sum up, we get:
$$\begin{cases} t^N = \frac{\delta}{3}(1 + 2\theta) \\ T^N = \frac{\delta}{3}(2 + \theta) \end{cases} \tag{12}$$
and
$$\begin{cases} r\left(t^N, T^N\right) = \frac{\delta}{9}H(1 + 2\theta)^2 \\ R\left(T^N, t^N\right) = \frac{\delta}{9}H(2 + \theta)^2 . \end{cases} \tag{13}$$
□

B.2.2 Stackelberg equilibrium where the home country leads.

1. For $t \leqslant \delta$, $T(t) = \frac{1}{2}(\delta + t)$ and $t \leqslant T$, the objective function of the leader becomes:

$$r(t, T(t)) = th + tH\frac{\delta - t}{2\delta}.$$

Since $t \leqslant \delta$, we get:

$$\frac{\partial r(t, T(t))}{\partial t} = \frac{2\delta h + H\delta - 2tH}{2\delta} \geqslant \frac{H}{2}(2\theta - 1) \geqslant 0.$$

If $\theta \geqslant 1/2$, we get:

$$t^L = \delta = T^F.$$

An interior solution exists if and only if: $\theta \leqslant 1/2$.

$$\frac{\partial r(t, T(t))}{\partial t} = \frac{2\delta h + H\delta - 2tH}{2\delta} = 0$$

which yields:

$$\begin{cases} t^L = \delta\left(\theta + \frac{1}{2}\right) \\ T^F = \frac{\delta}{2}\left(\theta + \frac{3}{2}\right) \end{cases}$$

where $T^F \geqslant t^L \Leftrightarrow \frac{\delta}{2}\left(\theta + \frac{3}{2}\right) \geqslant \delta\left(\theta + \frac{1}{2}\right) \Leftrightarrow \theta \leqslant \frac{1}{2}$.

2. For $\delta \leqslant t \leqslant \frac{\delta}{\theta}$, $T(t) = t$, the objective function of the leader is equal to:

$$r(t, T(t)) = th,$$

and

$$\begin{aligned} \frac{\partial r(t, T(t))}{\partial t} &= h > 0, \\ t^L &= T^F = \frac{\delta}{\theta}. \end{aligned}$$

3. For $\frac{\delta}{\theta} \leqslant t$, $T(t) = \frac{1}{2}\left(\frac{\delta}{\theta} + t\right)$ and $t \geqslant T$, the objective function of the leader becomes:

$$r(t, T(t)) = th\left(1 - \frac{1}{2\delta}\left(t - \frac{\delta}{\theta}\right)\right),$$

and then

$$\frac{\partial r(t, T(t))}{\partial t} = \frac{h}{2\delta}\left[2\delta + \frac{\delta}{\theta} - 2t\right].$$

Since $\frac{\delta}{\theta} \leqslant t$, we get:

$$\begin{aligned} \frac{\partial r(t, T(t))}{\partial t} &\leqslant \frac{h}{2\theta}(2\theta - 1) \leqslant 0 \Leftrightarrow \theta \leqslant \frac{1}{2} \\ &\Leftrightarrow t^L = \frac{\delta}{\theta} = T^F. \end{aligned}$$

If $\theta \geqslant \frac{1}{2}$, there is then an interior solution which yields:

$$\begin{cases} t^L = \delta\left(1 + \frac{1}{2\theta}\right) \\ T^F = \frac{1}{2}\delta\left(1 + \frac{3}{2\theta}\right) \end{cases}$$

where $T^F < t^L \Leftrightarrow \frac{\delta}{2}\left(1 + \frac{3}{2\theta}\right) < \delta\left(1 + \frac{1}{2\theta}\right) \Leftrightarrow \theta \geqslant \frac{1}{2}$.

4. From the previous analysis, we have to compare the payoff levels in several cases.

For $\theta \leqslant \frac{1}{2}$,

$$r\left(\frac{\delta}{\theta},\frac{\delta}{\theta}\right) = \delta H > r\left(\delta\left(\theta+\frac{1}{2}\right),\frac{\delta}{2}\left(\theta+\frac{3}{2}\right)\right) = \frac{\delta H}{8}\left(2\theta+1\right)^2.$$

For $\theta \geqslant \frac{1}{2}$,

$$r\left(\delta,\delta\right) = \delta h < r\left(\delta\left(1+\frac{1}{2\theta}\right),\frac{1}{2}\delta\left(1+\frac{3}{2\theta}\right)\right) = \frac{\delta h}{8}\left(2+\frac{1}{\theta}\right)^2.$$

To summarize, we obtain:

$$\begin{array}{ll} t^L = T^F = \frac{\delta}{\theta} & for \quad \theta \leqslant \frac{1}{2}, \\ \left\{\begin{array}{l} t^L = \delta\left(1+\frac{1}{2\theta}\right) \\ T^F = \frac{1}{2}\delta\left(1+\frac{3}{2\theta}\right) \end{array}\right. & for \quad \theta \geqslant \frac{1}{2}, \end{array} \tag{14}$$

and

$$\begin{array}{l} r\left(t^L,T^F\right) = \left\{\begin{array}{ll} H\delta & \text{if} \quad \theta \leqslant \frac{1}{2} \\ \frac{\delta h}{8}\left(2+\frac{1}{\theta}\right)^2 & \text{if} \quad \theta \geqslant \frac{1}{2} \end{array}\right. . \\ R\left(t^L,T^F\right) = \left\{\begin{array}{ll} H\frac{\delta}{\theta} & \text{if} \quad \theta \leqslant \frac{1}{2} \\ \frac{\delta h}{16}\left(2+\frac{3}{\theta}\right)^2 & \text{if} \quad \theta \geqslant \frac{1}{2} \end{array}\right. \end{array} \tag{15}$$

□

B.2.3 Stackelberg equilibrium where the foreign leads.

1. For $T \leqslant \delta\sqrt{\theta}$, $t\left(T\right) = \frac{1}{2}\left(\delta+T\right)$ and $t \geqslant T$, the objective function of the foreign country is then:

$$\begin{aligned} R\left(T,t\left(T\right)\right) &= TH + Th\frac{\delta - T}{2\delta} \\ \frac{\partial R\left(T,t\left(T\right)\right)}{\partial T} &= \frac{2\delta H + h\delta - 2hT}{2\delta} \geqslant \frac{2\delta H + h\delta - 2h\delta\sqrt{\theta}}{2\delta} \\ &= \frac{2\left(H - h\sqrt{\theta}\right) + h}{2} > 0, \end{aligned}$$

and then

$$\left\{\begin{array}{l} T^L = \delta\sqrt{\theta} \\ t^F = \frac{\delta}{2}\left(1+\sqrt{\theta}\right) \end{array}\right.$$

which satisfies $t \geqslant T$.

2. For $T \geqslant \delta\sqrt{\theta}$, $t\left(T\right) = \frac{1}{2}\left(\delta\theta+T\right)$ and $T \leqslant t$, the objective function of the foreign country is then:

$$\begin{aligned} R\left(T,t\left(T\right)\right) &= TH\left(1 - \frac{T-\delta\theta}{2\delta}\right), \\ \frac{\partial R\left(T,t\left(T\right)\right)}{\partial T} &= H\left(1 - \frac{T-\delta\theta}{2\delta}\right) - \frac{TH}{2\delta} = 0. \end{aligned}$$

To summarize, we obtain:

$$\left\{\begin{array}{l} t^F = \frac{\delta}{2}\left(1+\frac{3}{2}\theta\right) \\ T^L = \frac{\delta}{2}\left(2+\theta\right) \end{array}\right. \tag{16}$$

and

$$\left\{\begin{array}{l} r\left(t^F,T^L\right) = \frac{\delta}{16}H\left(2+3\theta\right)^2 \\ R\left(t^F,T^L\right) = \frac{\delta}{8}H\left(2+\theta\right)^2. \end{array}\right. \tag{17}$$

□

B.3 Comparing the tax rates.

From (12), (14) and (16), we get:

$$t^N < t^F < t^L$$

and

$$\begin{aligned} T^N &< T^L < T^F \quad for \quad \theta < \theta_1^c = \frac{\sqrt{7}-1}{2} \approx 0.822876, \\ T^N &< T^F < T^L \quad for \quad \theta \geq \theta_1^c. \end{aligned}$$

□

B.4 First-mover or second-mover advantage

From (13), (15) and (17), we get:
For $\theta \in [0,1]$,

$$R\left(t^L, T^F\right) > R\left(t^F, T^L\right).$$

If $\theta < \theta_2^c \approx 0.68896$,

$$r\left(t^L, T^F\right) > r\left(t^F, T^L\right).$$

If $\theta \geqslant \theta_2^c$,

$$r\left(t^L, T^F\right) \leqslant r\left(t^F, T^L\right).$$

□

B.5 Subgame Perfect Nash Equilibrium(s)

From Proposition 1, (13), (15) and (17), we get:

$$\begin{aligned} R\left(t^F, T^L\right) &> R\left(t^N, T^N\right) \quad and \quad R\left(t^L, T^F\right) > R\left(t^N, T^N\right), \\ r\left(t^F, T^L\right) &> r\left(t^N, T^N\right) \quad and \quad r\left(t^L, T^F\right) > r\left(t^N, T^N\right). \end{aligned}$$

When the home country plays *Early*, the foreign always prefers to follows; if the foreign plays *Late*, the home country prefers to lead. Thus the Stackelberg situation where the home country leads is a SPNE. In a similar way, we establish that the other Stackelberg outcome is a SPNE too.□

B.6 Risk dominance

First, we establish the proof of (1) :

If $\theta < \frac{1}{2}$,

$$\Pi = \frac{(2+\theta)\left(512 - 744\theta - 12\theta^2 + 162\theta^3 + 55\theta^4\right)}{1152\theta}\delta^2 H^2 > 0.$$

If $\theta \geqslant \frac{1}{2}$,

$$\Pi = \frac{81 + 296\theta + 136\theta^2 - 400\theta^3 - 248\theta^4 + 80\theta^5 + 55\theta^6}{1152\theta^2}\delta^2 H^2 > 0.$$

The proof of (2) is immediate from Proposition 1.□

B.7 The "big-country-higher-tax" rule

The Stackelberg equilibrium when the home country leads $\left(t^L, T^F\right)$ is characterized by:[12]

$$t^L = t^F = \frac{\delta}{\theta} \quad for \quad \theta \leqslant \frac{1}{2},$$

and

$$\begin{cases} t^L = \delta\left(1 + \frac{1}{2\theta}\right) \\ T^F = \frac{\delta}{2}\left(1 + \frac{3}{2\theta}\right) \end{cases} \quad for \quad \theta \geqslant \frac{1}{2}.$$

□

[12]This result is already presented in footnote 5, p.976, in Wang (1999) paper.